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Science | Sciences
Pacific Region
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STATE OF THE PACIFIC OCEAN 2011

Figure 1. The Pacific waters of British Columbia, Canada.

Context :

Pacific Canadian waters lie in a transition zone between coastal upwelling (California Current) and downwelling (Alaskan Coastal Current) regions, and experience strong seasonality and considerable freshwater influence. Variability is closely coupled with events and conditions throughout the tropical and North Pacific Ocean, experiencing frequent El Niño and La Niña events particularly over the past decade. The region supports important resident and migratory populations of invertebrates, groundfish and pelagic fishes, marine mammals and seabirds. Monitoring the physical and biological oceanographic conditions and fishery resources of this region is done by several government departments, to understand the natural variability of these ecosystems and how they respond to both natural and anthropogenic stresses. Support for these programs is provided by Fisheries and Oceans Canada (DFO), and Environment Canada. Contributors to this report are members of the Fisheries Oceanography Working Group of the DFO Centre for Science Advice Pacific Region (CSAP), with additional contributions from other Canadian and American fisheries and climate scientists.

This Science Advisory Report is from the February 15-16, 2012 State of the Pacific Ocean: 2012 Workshop. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Canada

SUMMARY

- This report summarises the thirteenth annual workshop on the state of physical, biological, and selected fishery resources of Canadian Pacific marine ecosystems.
- The average global temperature in 2011 was warmer than average almost everywhere, but not in the eastern Pacific Ocean, where cool waters have been present in almost every year since 2008, part of a Pacific-wide weather pattern associated with La Niña conditions of these years.
- Sea surface measurements from shore stations along the coast of British Columbia, and in the Strait of Georgia, confirm that ocean conditions were cooler in 2011 than in 2010.
- The spring bloom of phytoplankton in the Strait of Georgia in 2011 was later than normal, due to stronger winds of March and early April, but once it began the growth was unusually strong. Observations of this bloom by satellite and by ship-based surveys reveal that it peaked in June and extended into July, and had unusually high biomass of the harmful algae *Heterosigma akashiwo*.
- The copepod community of zooplankton on the Oregon continental shelf was dominated by lipid-rich "northern" copepods in 2011, suggesting strong survivals for coho and Chinook salmon returning to the Columbia River in 2012 and 2013. When combined with other factors, the general assessment is for average returns of these salmon stocks.
- Off the west coast of Vancouver Island, the zooplankton community, as well as other oceanic indicators, was more or less average, implying average marine survivals for salmon that went to sea in 2011.
- Within the Strait of Georgia, conditions in 2011 were generally favourable for juvenile sockeye salmon, whereas poor returns are projected for coho salmon returning in 2012, Chinook salmon returning in 2013 and 2014, and chum salmon returning in 2013.
- An estimated 5 million Fraser River sockeye returned to British Columbia coastal waters in 2011, well within the range of predictions provided the previous year. This number contrasts with the record high of about 30 million in 2010 and record low of 1 million in 2009. The 10% and 90% range of predictions for returns in 2012 are 0.7 and 7 million sockeye.
- A detailed examination of smolt survivals of Chilko Lake sockeye salmon revealed a sharp pattern break in 1990, when the trend in marine survival changed from increasing prior to 1990 to decreasing after 1990. In contrast, marine survivals for Fraser pink salmon were without trend, and recent increases in pink salmon returns were attributed to be primarily the result of reduced fishing.
- A separate research effort, using ecosystem models that include most marine species and climate variability in the Strait of Georgia, identified a shift to lower growth rate of phytoplankton beginning in 1990 and continuing to present, which is attributed to stronger wind speeds in spring and summer since 1990. This lower primary production is manifested in the model as declines, after 1990, of coho and Chinook salmon, herring, dogfish, and killer whales.
- 2011 saw decreased pink shrimp biomass west of Vancouver Island from higher values in 2009 and 2010, likely as a result of warmer waters in spring two years previously when the shrimp were young.
- Biomass indices for most groundfish species in Hecate Strait and Queen Charlotte Sound are trending upwards after several years of decline.

- Eulachon populations coast-wide remain at low levels, while Pacific sardine biomass off the west coast of Vancouver Island increased in 2011 compared to 2010.
- Herring biomass forecasts for Haida Gwaii and Central Coast stocks are below fishery thresholds, while for Strait of Georgia and Prince Rupert stocks, forecasts are above thresholds. Declines in lengths and weights-at-age of post-recruit BC herring since the 1970s continue, and is not believed to be due to fishing.
- Breeding success of Triangle Island Cassin's Auklets in 2011 was better than the long-term average and well above that of 2010.
- In Pacific Rim National Park Reserve, 2011 seabird abundance remained high and similar to 2010. Intertidal bivalves in the Barkley Sound part of this reserve were about average, while manila clams continue to decline. SARA-listed Olympia oyster has increased, but remains less common than in the late 1990s.
- Polychlorinated biphenyls (PCBs) declined significantly in Salish Sea harbour seals between 1984 and 2009, based on observations at a repeat-sampling station in the southern part of this sea. Polybrominated diphenyl ethers (PBDEs) continued to increase until mid-2000s, followed by a decline.
- Lowest oxygen concentrations have been recorded off southwest Vancouver Island since 2002, but mortality of bottom life has not been reported.
- Deep water in the North Pacific Ocean is already the most acidic in the global ocean and the British Columbia continental shelf might see negative impacts of this feature sooner than most oceanic waters.
- Scientists hope to collaborate in the next year to produce more quantitative ocean indices to rank the health of the ocean and its marine species, as part of an ongoing ecosystem approach to management (EAM).

BACKGROUND

This report summarises the thirteenth annual workshop on the state of physical, biological, and selected fishery resources of Canadian Pacific marine ecosystems. The region supports important resident and migratory populations of invertebrates, groundfish and pelagic fishes, marine mammals and seabirds. Monitoring the physical and biological oceanographic conditions and fishery resources of the Pacific Region is done semi-regularly by scientific staff in several government departments, to understand the natural variability of these ecosystems and how they respond to both natural and anthropogenic stresses. Support for these programs is provided by Fisheries and Oceans Canada, Environment Canada, Parks Canada and various other agencies. Additional information is provided by the US National Oceanographic and Atmospheric Administration (NOAA), University of Victoria, Simon Fraser University, and the University of British Columbia.

Information for this report was presented at the annual meeting of the Fisheries Oceanography Working Group (FOWG) in Nanaimo, BC, on Feb. 15 to 16, 2012 chaired by Jim Irvine and Bill Crawford, both of Fisheries and Oceans Canada. This summary report is based on contributions by participants.

More details are provided in Irvine, J.R. and W.R. Crawford. 2012. State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/072.

ASSESSMENT

The average global temperature in 2011 was warmer than average almost everywhere, but not in the eastern Pacific Ocean, where cool waters have been present in almost every year since 2008, part of a Pacific-wide weather pattern associated with La Niña conditions of these years. These La Niña conditions were most active in winter, with a stronger North Pacific High Pressure System and stronger, cool westerly winds over the ocean west of British Columbia. This pattern of cool ocean surface water was interrupted only briefly in the winter of 2010, when El Niño winds brought warmer waters to our region.

The North Pacific Current increased its eastward flow speed in the eastern North Pacific Ocean through the winter of 2011 to 2012, with normal flow otherwise. This current is expected to carry tsunami debris from Japan. Although some objects have already arrived, it is expected that the main part will arrive next winter or through 2013.

Sea surface measurements from shore stations along the coast of British Columbia, and in the Strait of Georgia, confirm that ocean conditions were cooler in 2011 than in 2010. Relatively fresh surface waters within the Strait of Georgia in 2011 were at least partly a consequence of a heavy snow pack. Ocean surface waters on the British Columbia continental shelf were fresher than normal in the summer of 2011.

Weather conditions in late winter and early spring determine the timing and intensity of growth of phytoplankton that feed the food chain that provides necessary prey for juvenile fish at a critical time in their life. The spring bloom of phytoplankton in the Strait of Georgia in 2011 was later than normal, due to stronger winds of March, but once it began the growth was unusually strong. Observations of this bloom by satellite and by ship-based surveys reveal that it peaked in June and extended into July, and had unusually high biomass of the harmful algae *Heterosigma akashiwo*. Blooms of this phytoplankton have been observed in previous years in nearshore waters of the Strait of Georgia during May through October and have been postulated as perhaps adversely affecting juvenile sockeye salmon during their seaward migration.

Studies of zooplankton are undertaken along the west coast and in the Gulf of Alaska. These tiny drifting animals feed mainly on phytoplankton, and in turn are prey for many juvenile fish. The species composition of zooplankton and their biomass are useful predictors for fisheries. The copepod community of zooplankton on the Oregon continental shelf was dominated by lipid rich "northern" copepods in 2011. Although other factors are important, this observation, by itself, indicates strong survivals for coho and Chinook salmon returning to the Columbia River in 2012 and 2013.

Further north, off the west coast of Vancouver Island, the zooplankton community was of normal composition, except for a summer shift to warm-water oceanic zooplankton seaward of the southern Vancouver Island shelf. In deep-sea waters, zooplankton indices were consistent with cool ocean conditions. When the zooplankton community composition is combined with other environmental indicators for the west coast of Vancouver Island and Oregon, 2011 conditions for juvenile salmon migrating to sea were rated as average. This rating affects Columbia River salmon as well as those from Vancouver Island itself.

Within the Strait of Georgia, conditions in 2011 were generally favourable for juvenile sockeye salmon from the Fraser River, whereas poor returns are projected for coho salmon returning in 2012, Chinook salmon returning in 2013 and 2014, and chum salmon returning in 2013.

An estimated 5 million Fraser River sockeye returned to British Columbia coastal waters in 2011, well within the range of predictions provided the previous year. This number contrasts with the record high of about 30 million in 2010 and record low of 1 million in 2009. Lower returns in 2011 compared to 2010 are attributed mainly to reduced survival of young salmon in

freshwater. The primary estimator of sockeye returns is based on the number of parent spawners four years earlier, because most sockeye return to their natal river at age four, after spending two years at sea and two years in freshwater. On this basis, the prediction for 2012 returns is 0.7 million to 7 million, at the 10% to 90% probability distribution. These numbers are lower than average, due to fewer spawning sockeye in 2008. Fraser River sockeye returns in 2013 might be lower than average as well, due to fewer parent spawners in 2009, combined with generally favourable conditions in the Strait of Georgia in 2011, noted previously.

As part of ongoing research into year-to-year changes in ocean conditions and their impact on salmon survival at sea, scientists have examined survivals of a single stock of sockeye, from Chilko Lake in the Fraser River basin. By comparing returns of the small numbers of those returning at age five with the larger numbers returning at age four, they have revealed a sharp pattern break in 1990, when the trend in marine survival changed from increasing prior to 1990 to decreasing after 1990. In contrast, marine survivals for Fraser pink salmon were without trend, and recent increases in pink salmon returns were determined to be primarily the result of reduced fishing. Another research effort, using ecosystem models that include most marine species and climate variability in the Strait of Georgia, identified a shift to lower growth rate of phytoplankton beginning in 1990 and continuing to present that is attributed to stronger wind speeds in spring and summer since 1990. This lower primary production is manifested in the model as declines, after 1990, of coho and Chinook salmon, herring, dogfish, and killer whales.

Other biological findings in 2011 include decreased pink shrimp biomass west of Vancouver Island from higher values in 2009 and 2010, likely as a result of warmer waters in spring two years previously when the shrimp were young.

Biomass indices for most groundfish species in Hecate Strait and Queen Charlotte Sound are trending upwards after several years of decline.

Eulachon populations coast-wide are at low levels, while Pacific sardine biomass off the west coast of Vancouver Island increased in 2011 compared to 2010. Herring biomass forecasts for Haida Gwaii and Central Coast stocks are below fishery thresholds, while for Strait of Georgia and Prince Rupert stocks, forecasts are above thresholds.

Length-at-age and weight-at-age of post-recruit herring has decreased in all BC populations since the 1970s, including herring populations not fished during the herring roe fishery. Similar changes have occurred in California and some, but not all SE Alaska herring populations. Because size-at-age has decreased in areas not fished, this decrease is not believed to be due to fishing.

Sea birds can be effective indicators of the state of marine ecosystems because their large breeding aggregations can be relatively easily counted. Breeding success of Triangle Island Cassin's Auklets is strongly temporally matched with the phenology of an important prey species, the copepod *Neocalanus cristatus*. Breeding success of these auklets in 2011 was better than the long-term average and well above that of 2010.

In Pacific Rim National Park Reserve, 2011 seabird abundance remained high and similar to 2010. Most species displayed stable or improving population trends over the past 4 to 5 years. Intertidal bivalve population abundances in the Barkley Sound part of this reserve were about average relative to previous years. Manila clams continue to decline while there appears to be no spatial displacement of this species by the recently introduced varnish clams. SARA-listed Olympia oyster has displayed a recovering trend for the past 7 years but the numbers are still below those observed in late 1990s.

Persistent, bioaccumulative and toxic contaminants present a health risk to aquatic biota, notably those at the top of food web such as killer whales and seals. Recent analyses of biopsy samples taken from young harbour seals live-captured in the Salish Sea reveal that

polychlorinated biphenyls (PCBs) declined by 81% between 1984 and 2009 In contrast, the concentration of polybrominated diphenyl ethers (PBDEs) increased, with indication of a peak in PBDE levels in seals between 2003 and 2009 followed by a decline. This pattern would be consistent with the 2004 phase-out of two of the three PBDE products in Canada and the USA

Airborne surveys for oil on British Columbia waters have operated with increased efficiency since 2006, when more accurate sensors were added to the surveillance aircraft flights by Transport Canada, as part of the National Aerial Surveillance Program. Observations by this program, together with modelling and analyses of these observations from 2006 to 2010 by the Canadian Wildlife Service, reveal that the highest relative likelihood of detecting oil discharges occurred close to shore and, in particular, in the Strait of Georgia, the inside passage of the central coast, near Prince Rupert, and in Alberni Inlet. Although results are preliminary, results suggest that marina densities and intensity of local vessel activity (as opposed to international shipping) generally determine oil discharge patterns in the Pacific Region. There is some evidence that oil discharges have declined since the program was enhanced in 2006.

Scientists have reported alarmingly low oxygen concentrations in near-shore waters of the Oregon coast in summer, beginning in 2002 and most severely in 2006. High crab mortalities on the ocean bottom took place in these summers. Low oxygen concentrations (less than 1 ml/L) have also been observed off southwest Vancouver Island since 2002, with concentrations of 0.7 ml/L at 150 metres depth recorded in 2006 and 2009, the lowest in the 50-year record. Concentration was 1.0 and 1.1 ml/L in 2010 and 2011, respectively. Hypoxia on the Canadian shelf is much less severe than off Oregon and Washington, and mortality of bottom life has not been reported.

Deep water in the North Pacific Ocean already has the most acidic water in the global ocean and the British Columbia continental shelf might see negative impacts of this feature sooner than most oceanic waters.

CONCLUSION

Monitoring the physical and biological oceanographic conditions and marine fishery resources of the Pacific Region is essential to understanding the natural variability of these ecosystems and how they respond to natural and anthropogenic stressors. 2012 is the 13th consecutive year that "State of the Ocean" reports have been published in a consolidated format; a time series of tremendous value.

Developing standardized, quantitative indices to document changes in the health of the ocean and status of its marine species, as part of an ongoing ecosystem approach to management (EAM), is an important future direction for State of the Oceans reporting. Many time series extend much longer than the 13 years that State of Ocean reporting has been underway. Consistently monitored indices will enable the development of tools and products to advise resource managers on the impact and management options for human activities in the marine environment. Subsequent State of Ocean workshops and reports are expected to report on the continued development and application of ecosystem indicators.

SOURCES OF INFORMATION

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Irvine, J.R. and Crawford, W.R. 2012. State of the physical biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2011. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/072.

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